FULL FUEL CYCLE ANALYSES FOR AB1007

Presented at

California Energy Commission

Special Business Meeting

June 27, 2007

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AB 1007 requires CEC, in cooperation with ARB and other state agencies, to develop and adopt a state plan to increase the use of alternative transportation fuels

- One component of the plan is a ***full fuel cycle assessment*** of alternative transportation fuels considering emissions of:
  - Criteria air pollutants
  - Air toxics
  - Greenhouse gases
  - Water pollutants
  - Other substances that are known to damage human health
- “Alternative fuel” means a nonpetroleum fuel, including electricity, ethanol, biodiesel, hydrogen, methanol, or natural gas
- The plan shall set goals for 2012, 2017, 2022. CEC and ARB added 2030 and 2050

Full Cycle Analyses Goals

- Determine and understand the emissions footprints and other multimedia impacts of alternative fuels and vehicles
- Determine any “net material increases in emissions” (and identify possible mitigation)
- Use as guidance in developing the alternative fuels plan considering GHG emissions and petroleum displacement
- Use as metrics for helping to develop California’s “Low Carbon Fuel Standard” (E.O. S-01-07)
- Assessing GHG emission changes to advance other state policies such as California’s “Global Warming Solutions Act of 2006” (AB 32)

Draft FFCA Results were published in February 2007 and a joint workshop was held on March 2, 2007.

- Many constructive comments were received and can be summarized as follows:
  - Provide more documentation and more clearly describe each pathway
  - Perform sensitivity analyses on key assumptions
  - Provide WTT results on a neat basis
  - Analyze additional feedstocks/fuels
  - Errors and omissions were identified
  - Additional data was supplied to improve analysis accuracy
- TIAX incorporated comments into analysis
- FFCA “Well to Wheels” report posted on CEC’s website on June 22, 2007

  http://www.energy.ca.gov/2007publications/CEC-600-2007-004/CEC-600-2007-004-F.PDF

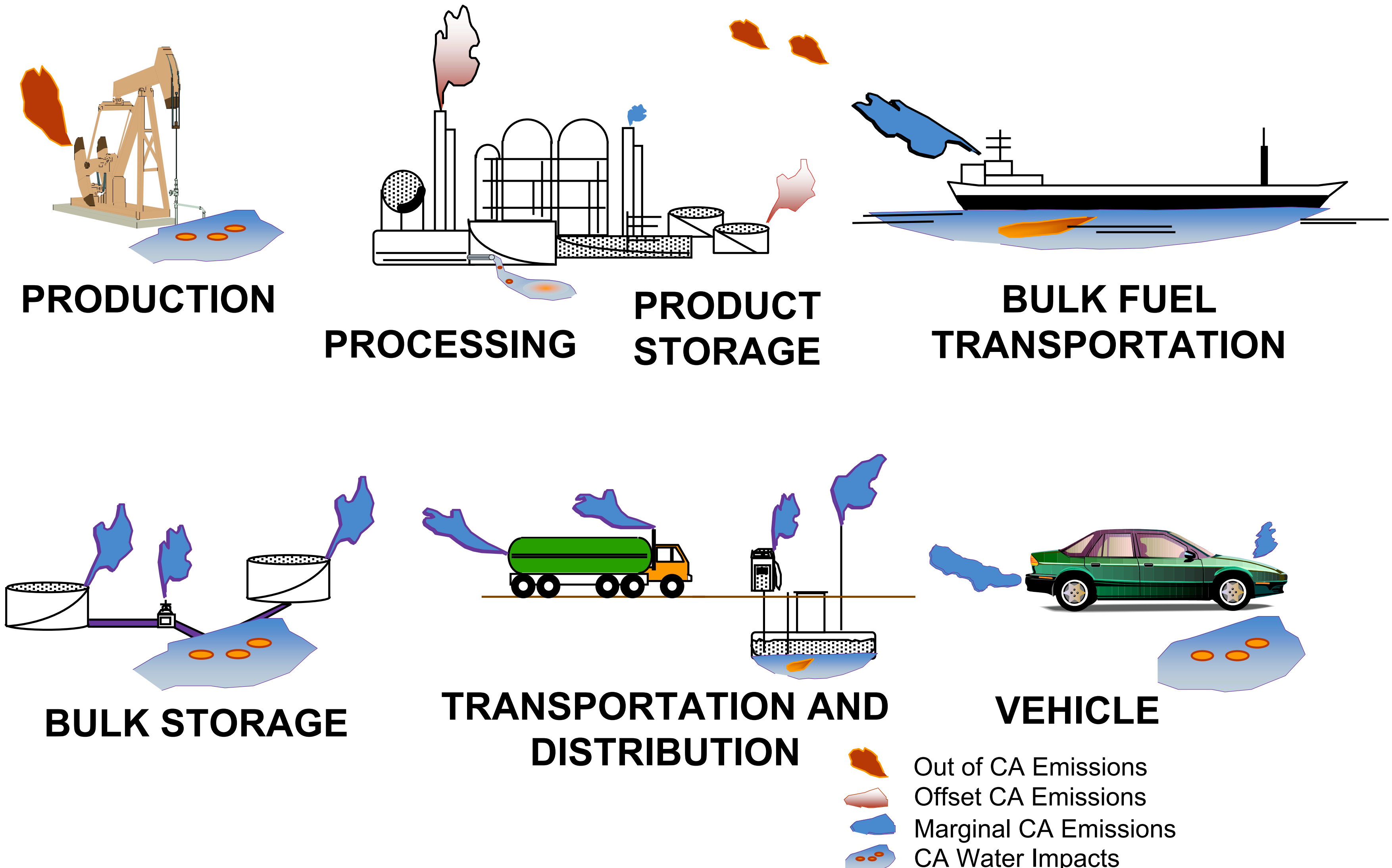
1 Introduction

2 **Methodology**

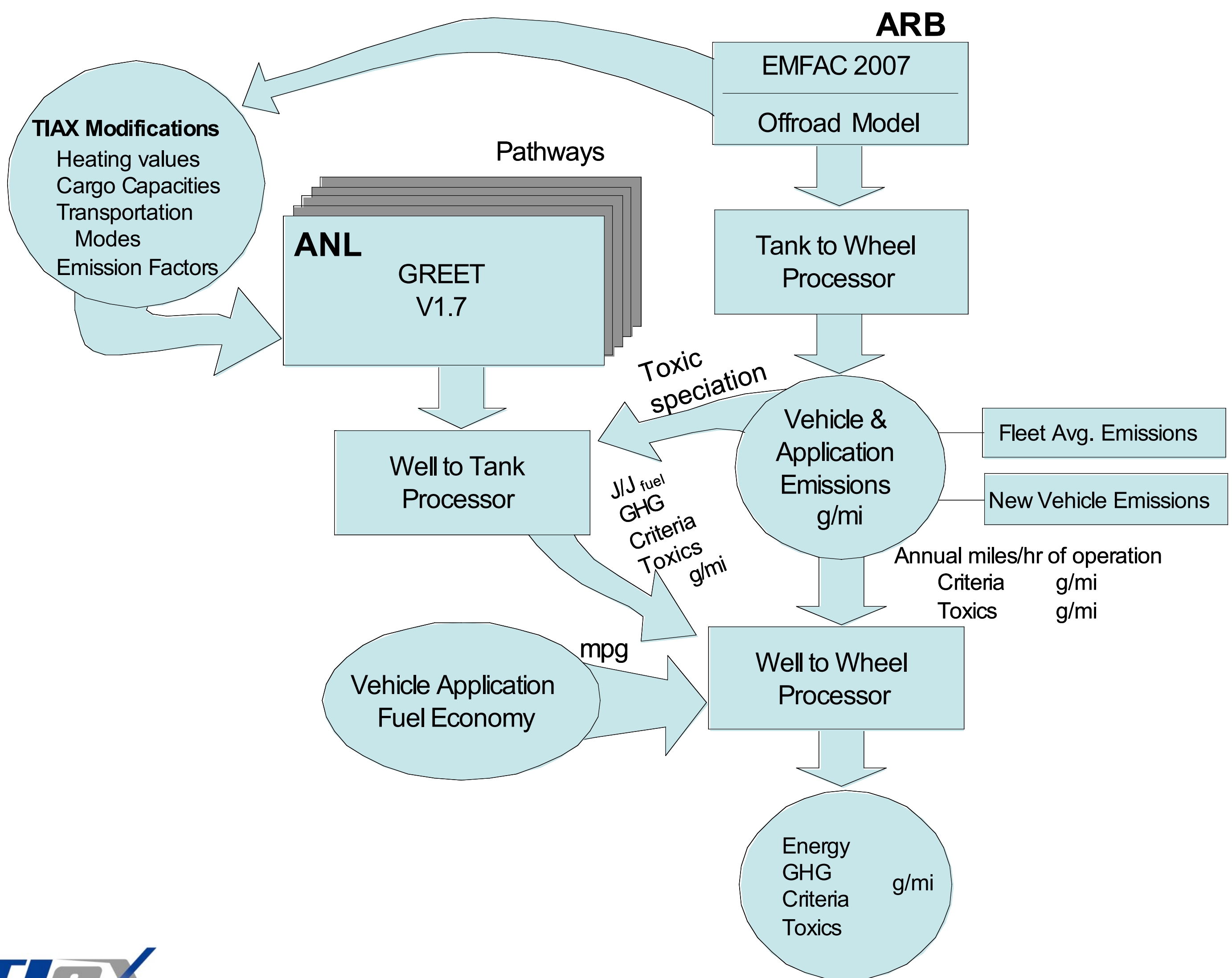
3 Example Results

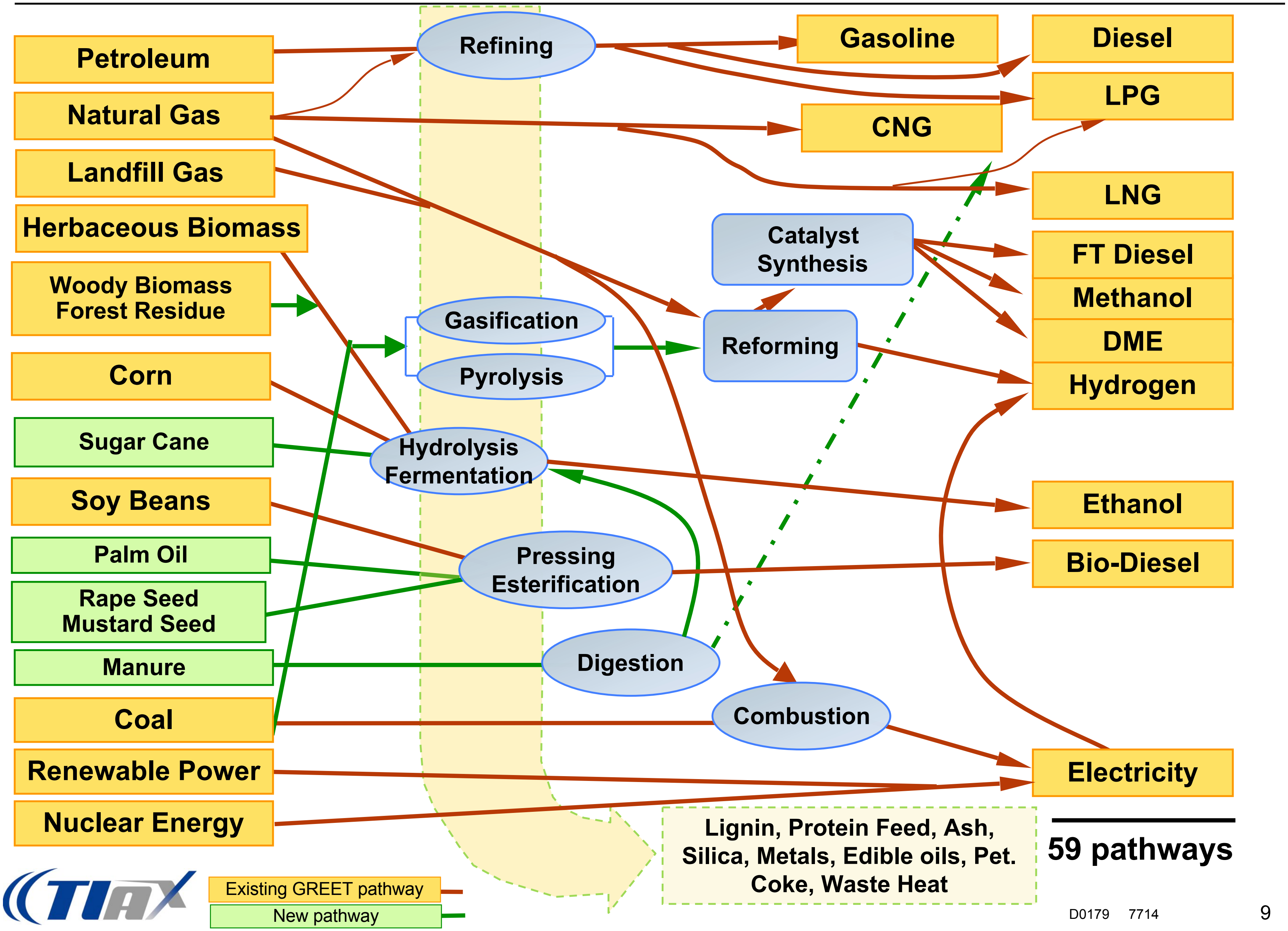
4 Implications

Number of emission events throughout fuel cycle

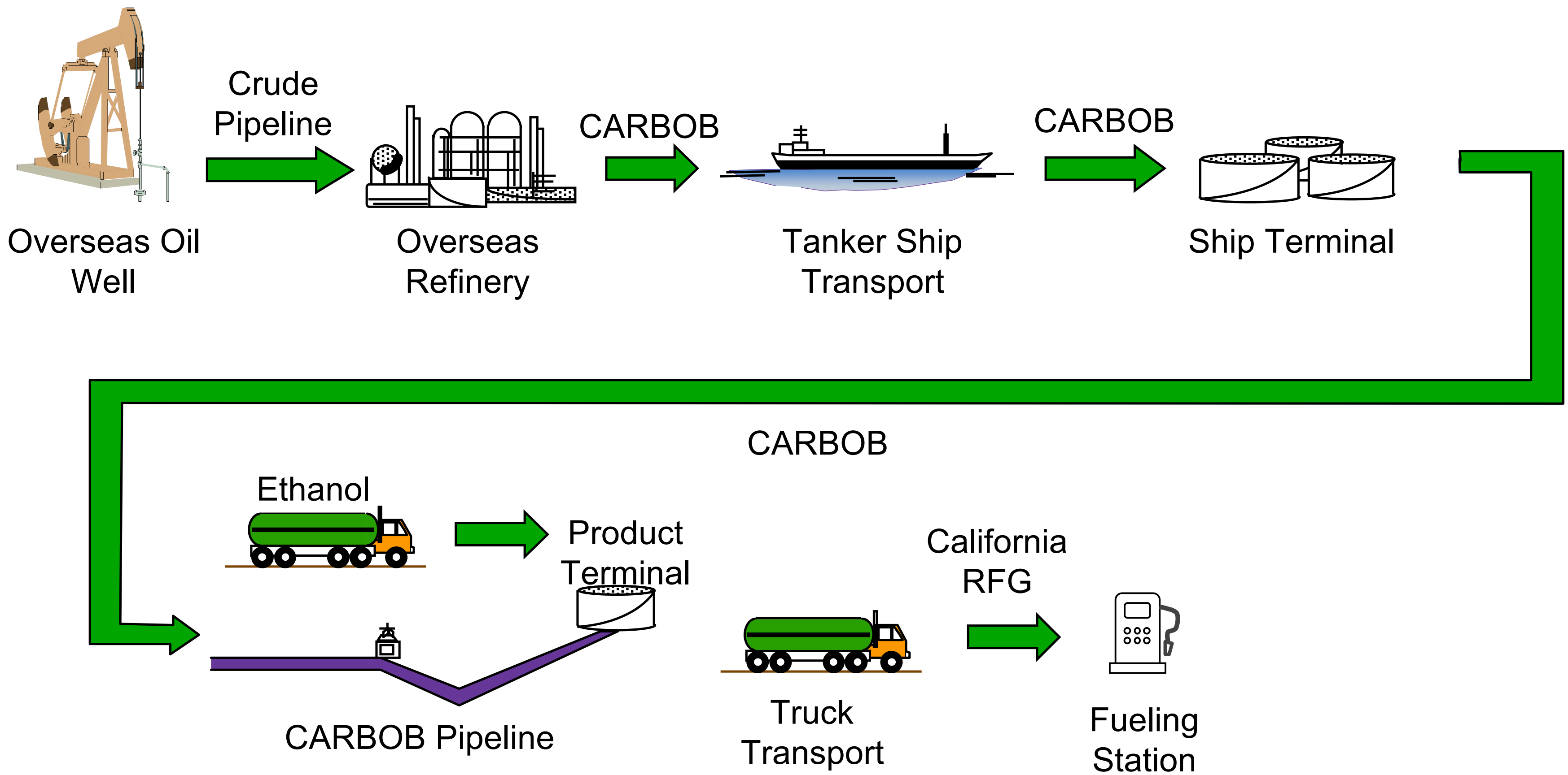


GREET (V1.7) Used as Backbone of Analysis Methodology

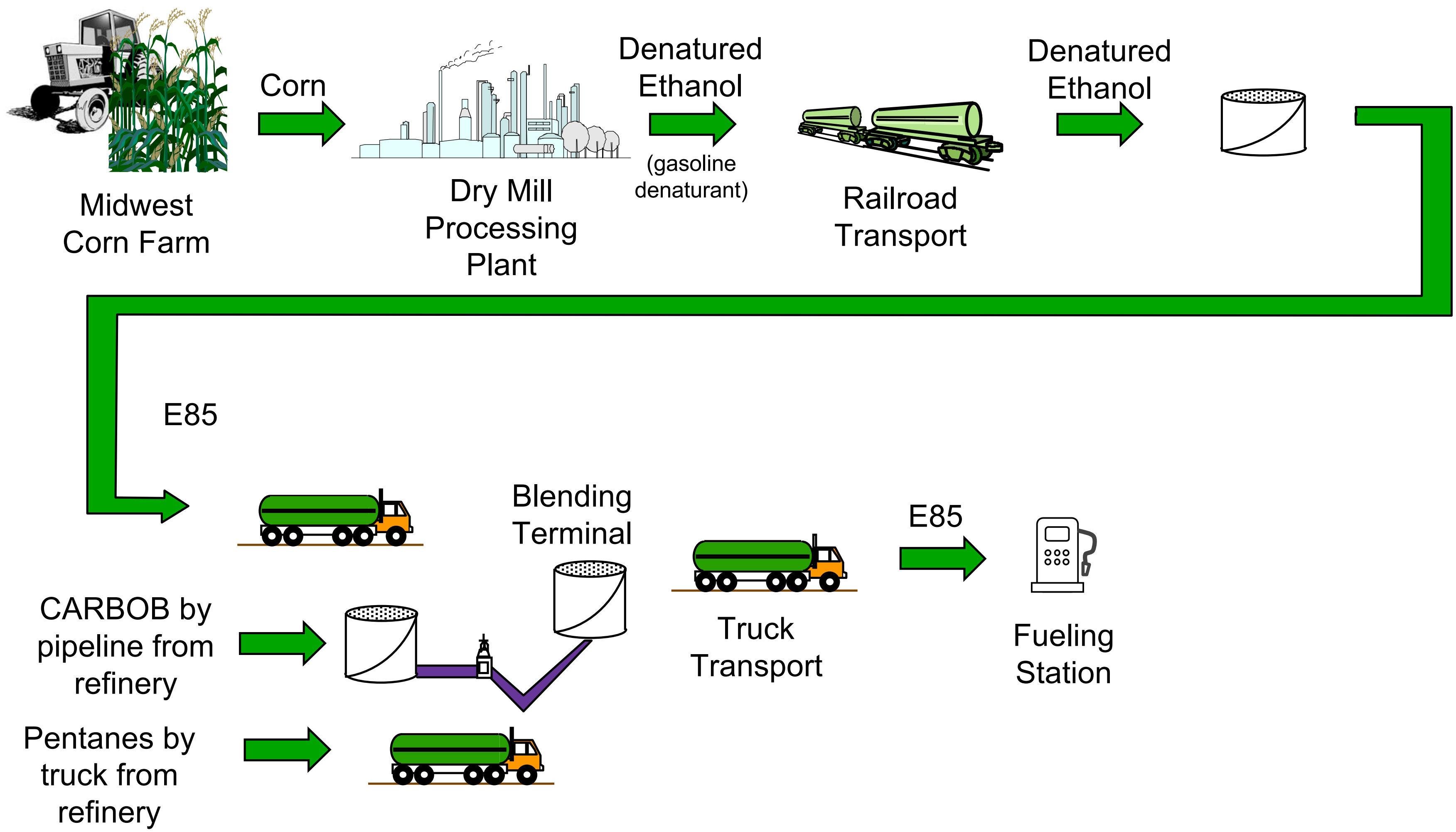



Petroleum
Natural Gas
Landfill Gas
Herbaceous Biomass
Woody Biomass Forest Residue
Corn
Sugar Cane
Soy Beans
Palm Oil
Rape Seed Mustard Seed
Manure
Coal
Renewable Power
Nuclear Energy
Refining
Gasification
Pyrolysis
Hydrolysis Fermentation
Pressing Esterification
Digestion
Combustion
Catalyst Synthesis
Reforming
Gasoline
CNG
Diesel
LPG
LNG
FT Diesel
Methanol
DME
Hydrogen
Ethanol
Bio-Diesel
Electricity
Lignin, Protein Feed, Ash, Silica, Metals, Edible oils, Pet. Coke, Waste Heat
59 pathways
Existing GREET pathway
New pathway

Imported CARBOB from Middle East to California RFG



Midwest Corn Based Ethanol Pathway to E85



Upward of 94 pathways X 2 vehicle applications X 4 analysis years X 2 vehicle fleets for criteria pollutants, WTT energy, WTW GHG, toxics, and water pollution

- Ten (10) Conventional Fuel Pathways
  - California RFG
  - California ULSD
- Twenty two (22) Blend Fuel Pathways
  - E10
  - Biodiesel (BD20)
  - FTD (30 percent with Ca ULSD)
  - E-Diesel – Renewable Diesel (30%)
- Sixty two (62) Neat Fuel Pathways
  - CNG – LNG – LPG
  - Ethanol – Methanol – DME
  - Electricity – Hydrogen – Biodiesel
  - Renewable diesel – FTD

Analysis Years: 2012, 2017, 2022, 2030

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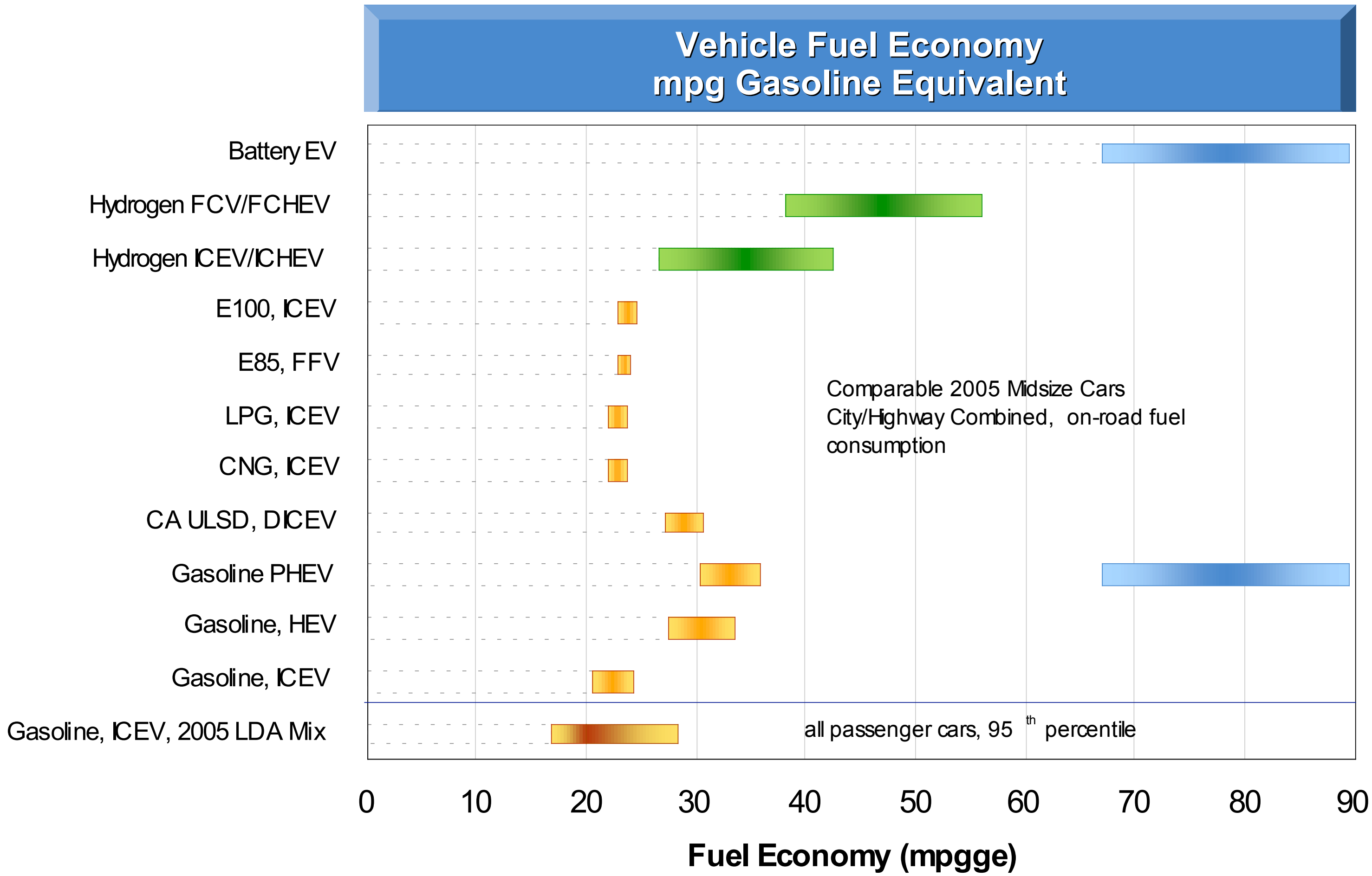
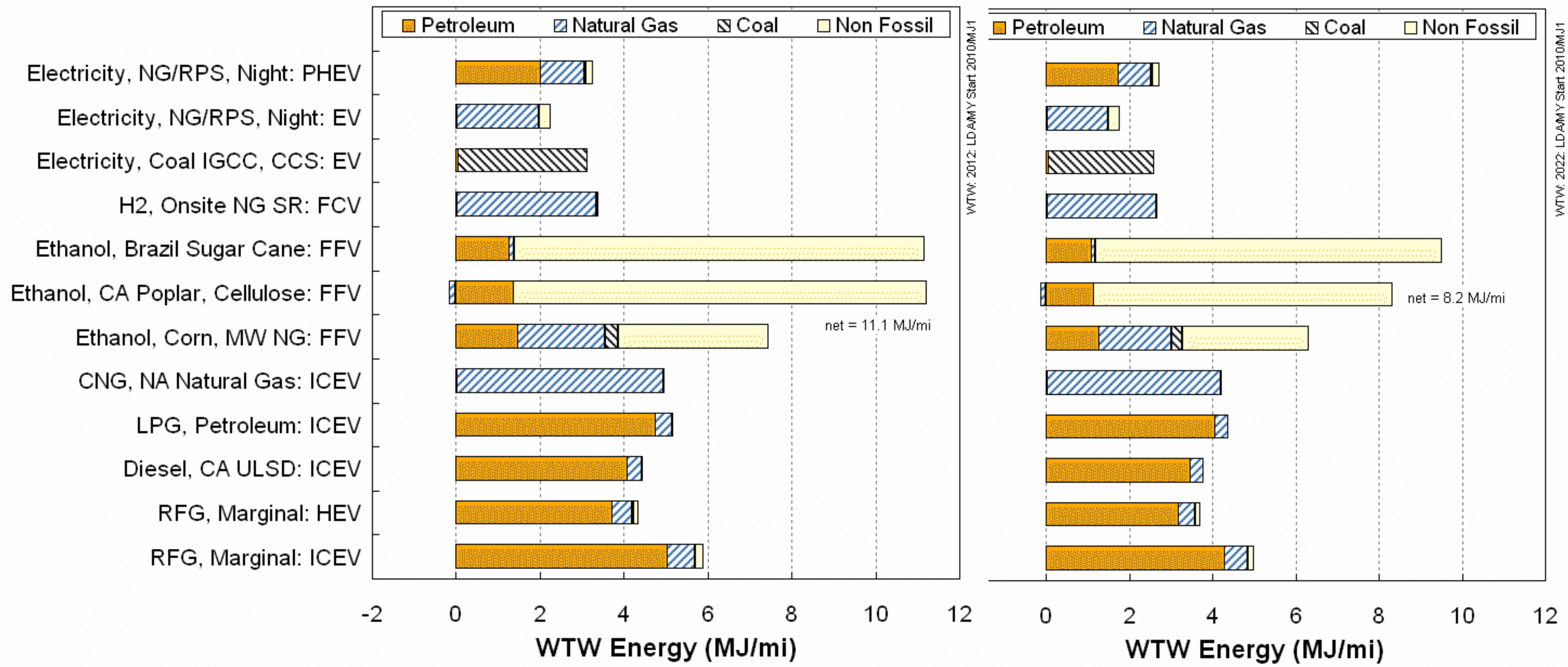
Assumed Midsized Auto Fuel Economy



"Well-to-Wheels" Energy Comparison Midsize Auto

WTW Energy
MJ (LHV) per Mile

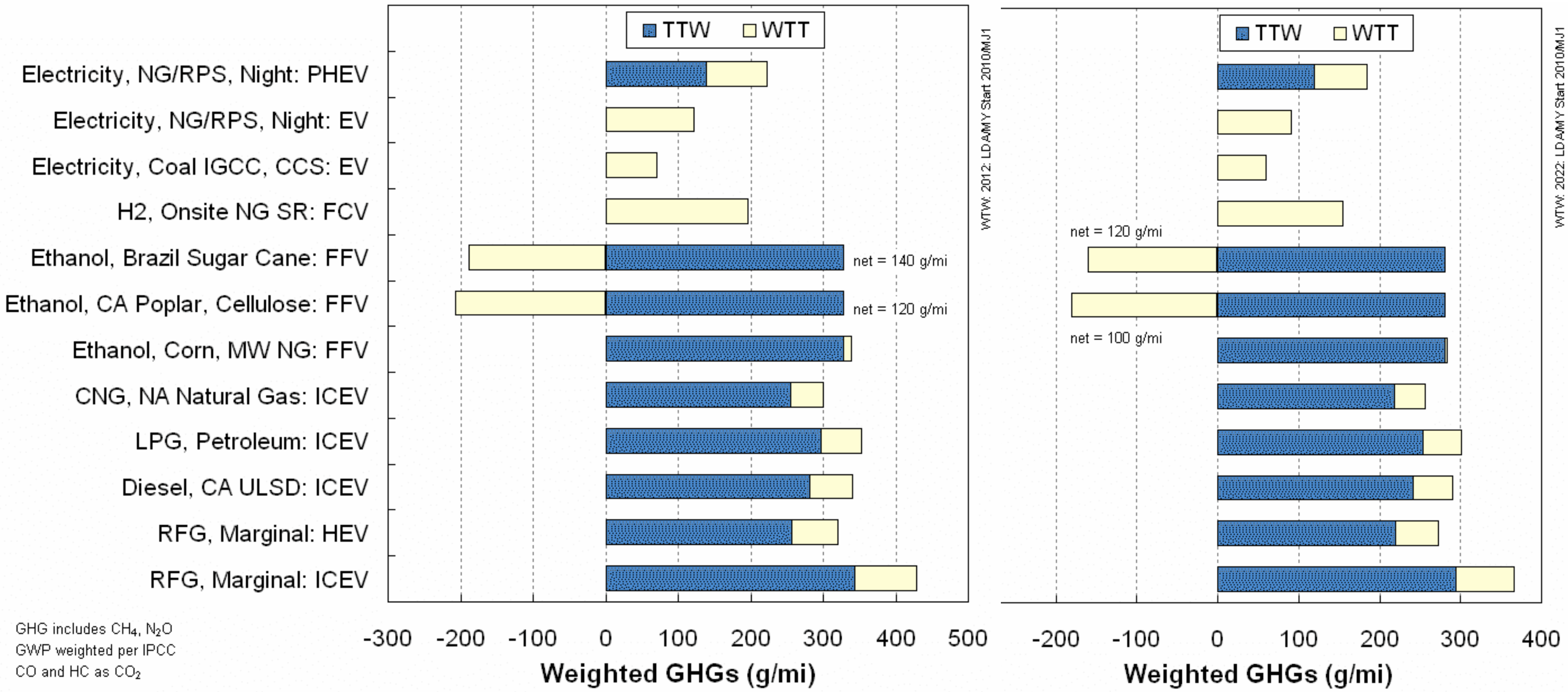


Midsize Cars in 2012
MY2010+

Midsize Cars in 2022
MY2010+

"Well-to-Wheels" GHG Emissions Midsize Auto

Greenhouse Gas Emissions
Grams of CO_2 Equivalent per Mile



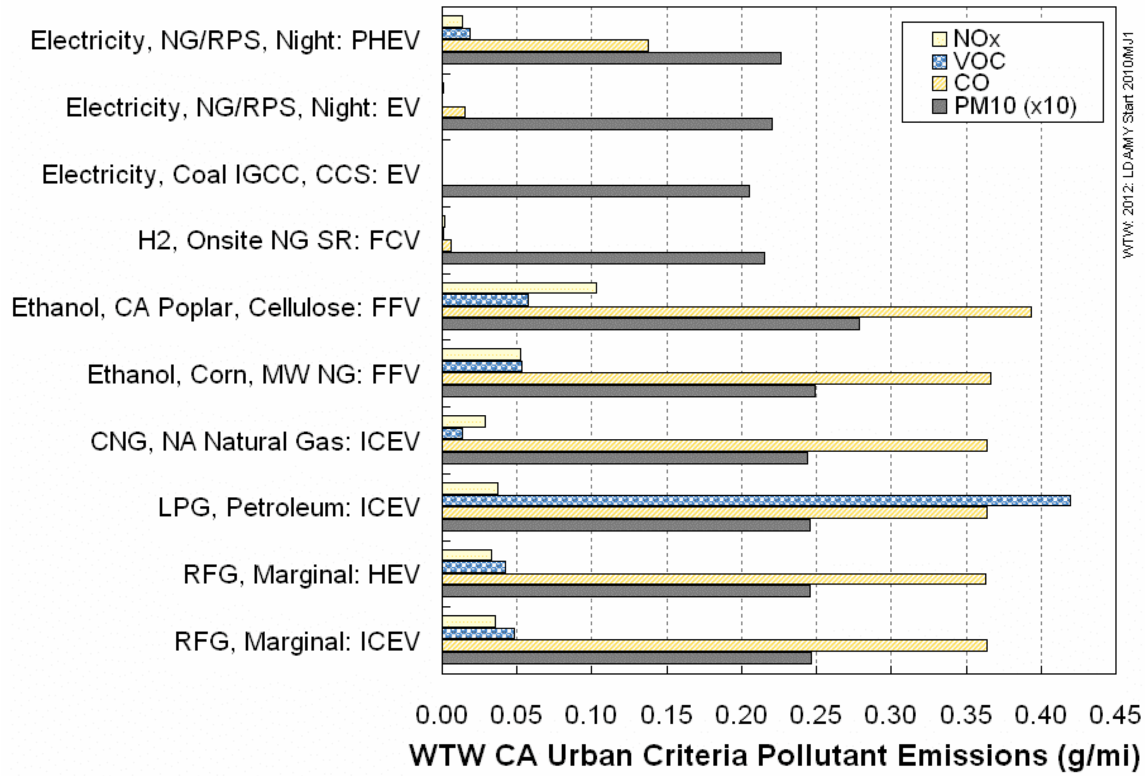
GHG includes CH_4, N_2O
GWP weighted per IPCC
CO and HC as CO_2

Midsize Cars in 2012
MY 2010+

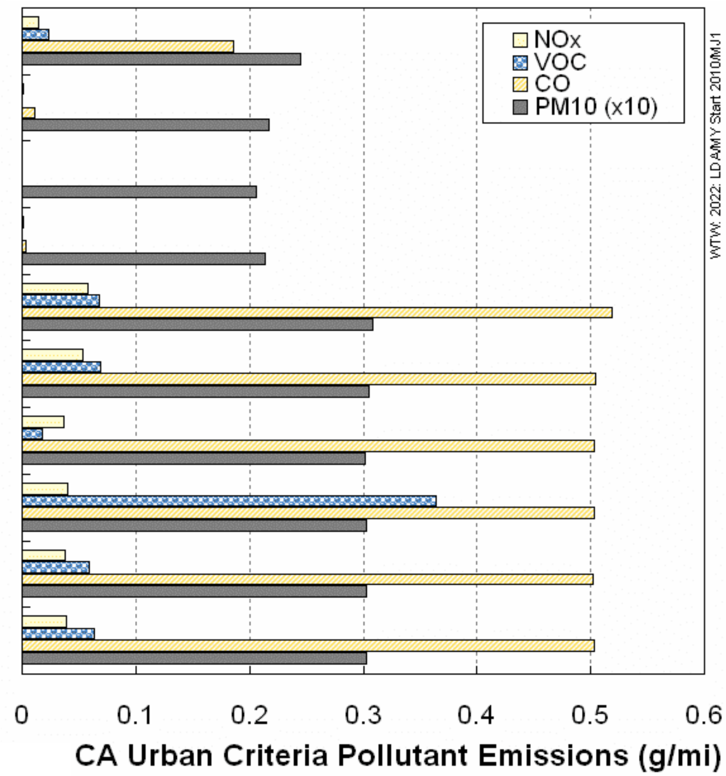
Midsize Cars in 2022
MY 2010+

"Well-to-Wheels" Criteria Pollutant Emissions Midsize Auto

California Urban Criteria Pollutants Emissions Grams per Mile



Midsize Cars in 2012
MY 2010+



Midsize Cars in 2022
MY 2010+

Well to Wheel GHG Observations

- GHG emissions depend on both the carbon content of the fuel and process energy inputs. In all cases except hydrogen and electricity, the vehicle GHG emissions dominate WTW emissions.
- GHG emissions from alternative fuels in off-road equipment with IC engines are comparable to the impacts for on road vehicles.
- A wide range of GHG emission factors are achieved for various hydrogen and electric generation pathways. Greater GHG emission reductions are largely due to the higher vehicle efficiency for electric drive technologies.
- An electric generation mix based on natural gas combined cycle power combined with California's RPS constraint is an appropriate mix for electric transportation and the electricity inputs for fuel production. The use of renewable power allows for the mitigation of GHG emissions from other processes, which is an option for all fuel providers.
- GHG emissions from biofuels production and use depend on agricultural inputs, allocation to byproducts, and the level and carbon intensity of process energy inputs.

Most pathways result in comparable emissions of criteria and toxic emissions for both midsize autos and urban buses

- Emissions from marine vessel and rail transport are the dominant source of fuel/feedstock delivery emissions in California. Agricultural equipment is also a significant source of emissions for biofuels.
- Diesel PM is the major contributor to weighted toxics emissions in California for the marginal fuel production analyses. Fuels that are delivered by ship or rail have the highest weighted toxics impact.
- Criteria pollutant emissions for electric transportation are comparable to, or lower than, those from conventional fuels. The lower emission levels result from efficient new power plants that are required to offset NOx and VOC emissions combined with very efficient vehicles.
- Emissions of NOx, VOC, and in some cases PM would need to be offset from new fuel production facilities in California.
- Fugitive losses and fuel spills are a source of benzene and 1-3 butadiene emissions associated with gasoline as well as PAHs from diesel. These emissions from fuel transport and delivery are largely eliminated with alternative fuels use.

Some Caveats….

- Land conversion effects could be very substantial effectively negating (or substantially lowering) GHG benefits of biofuels
  - Existing crop lands
  - Converting grasslands
  - Converting forests
  - Converting wetlands
- Analysis results are indicative of average GHG emission impacts for generic pathways. Detailed analysis needed for specific pathways.

Recommendations

- Continue to improve FFCA methodology
  - Revise and update inputs
  - Continue to monitor land conversion studies
- Use methodology to provide guidance on lowering carbon emissions from the transportation sector—fuel and vehicle

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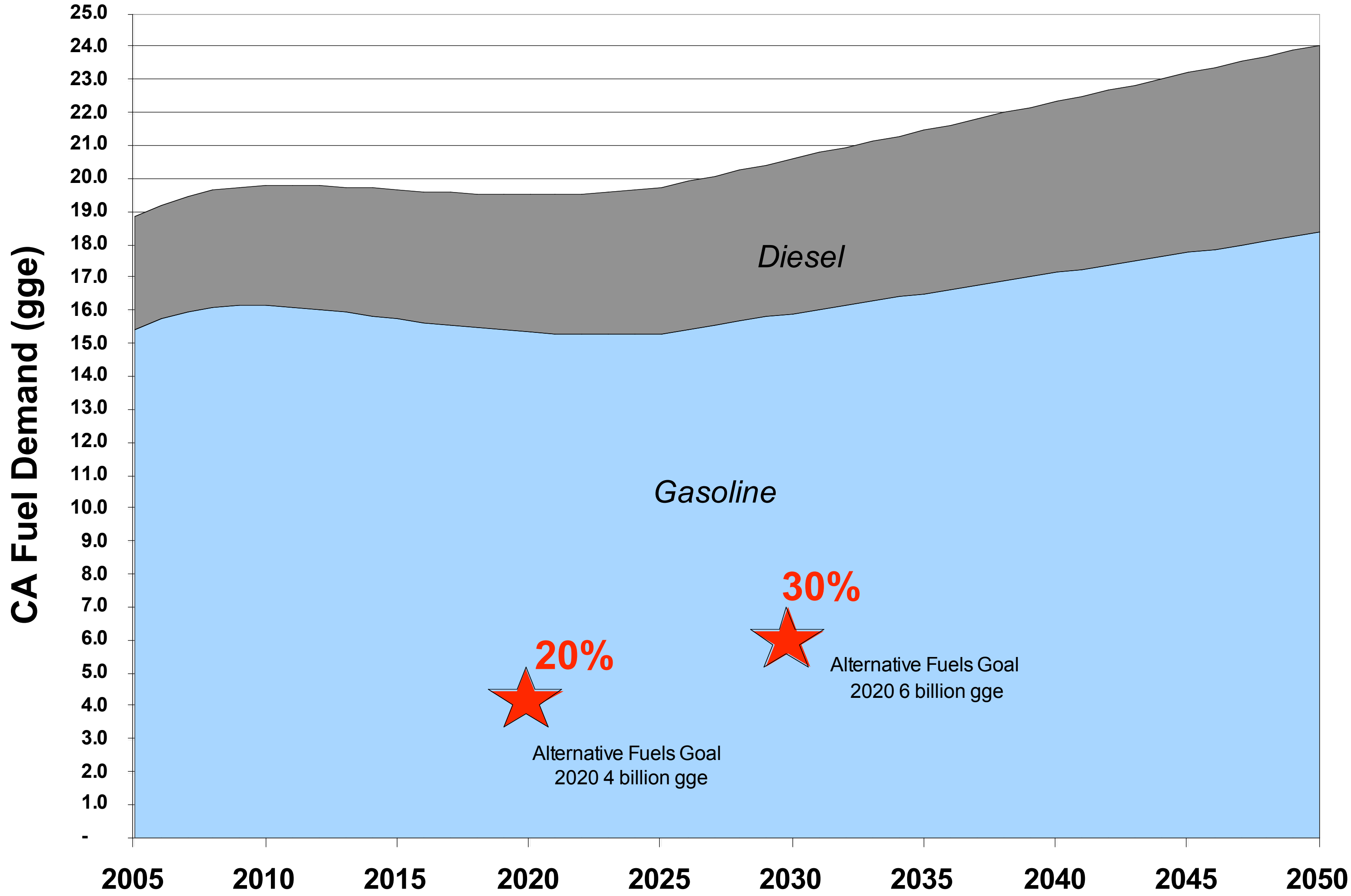
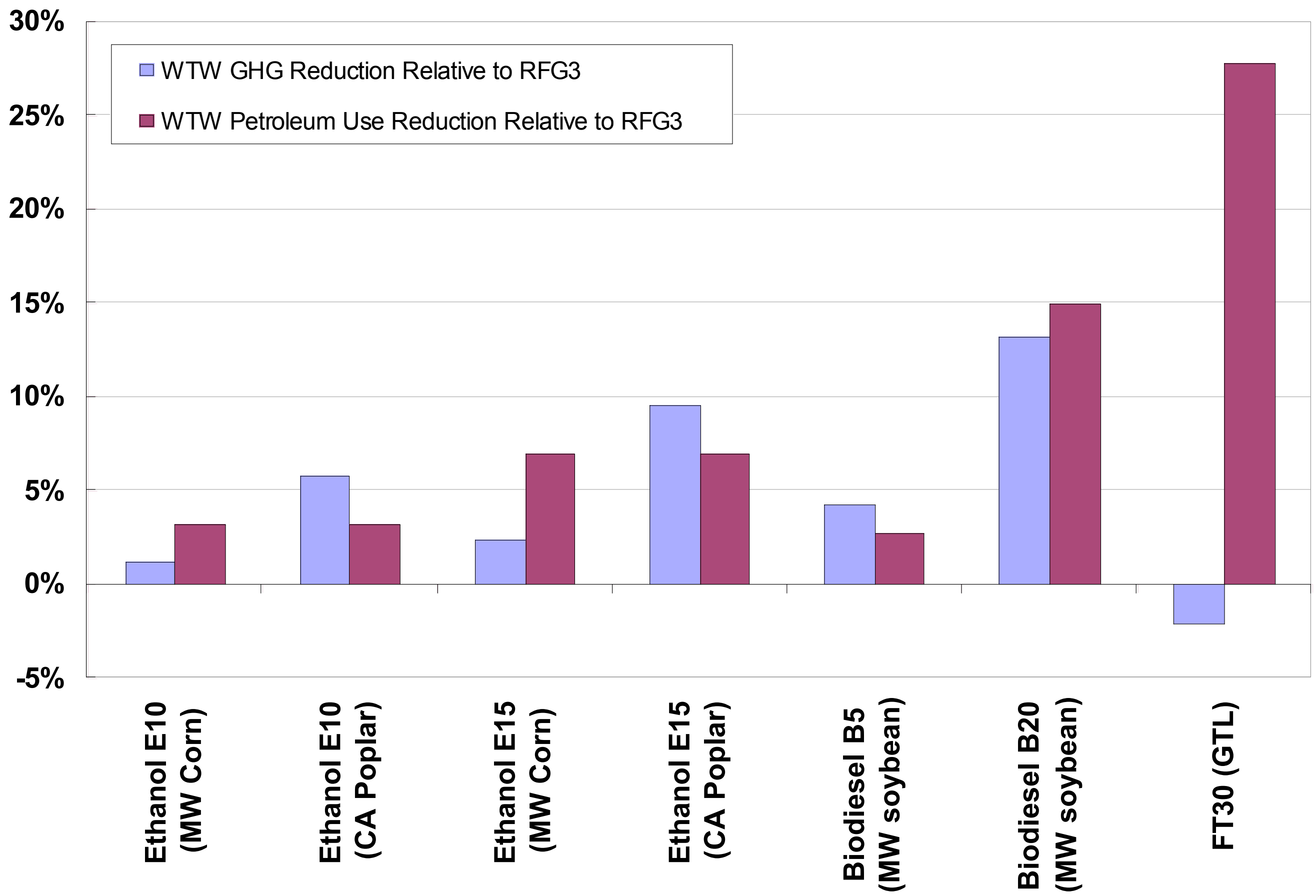
3. Example Results
4. **Implications**

California Alternative Fuels Goals (on road only)



GHG and Petroleum Impacts of Low Level Blend Strategies in Light Duty Vehicles



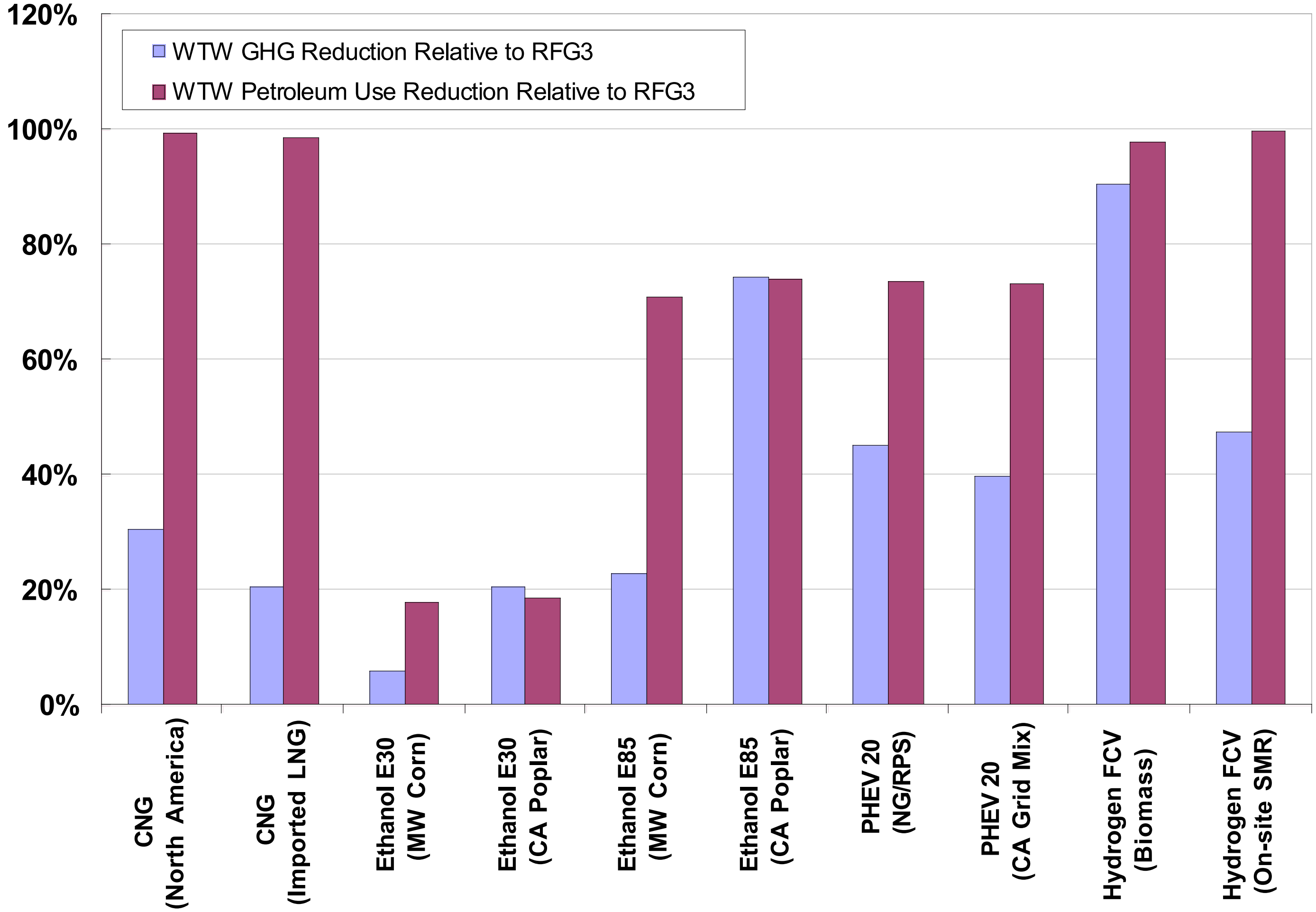
GHG Impact

- Cellulosic 17-20 million metric tons
- Corn 6 million metric tons

Petroleum Displacement

- E15 2 billion gallons
- E10 1.4 billion gallons

GHG and Petroleum Impacts of Alternative Fuels in Light Duty Vehicles



2050 GHG Impact

- PHEV 20 million metric tons
- E30 10-40 million metric tons
- H2 150 million metric tons

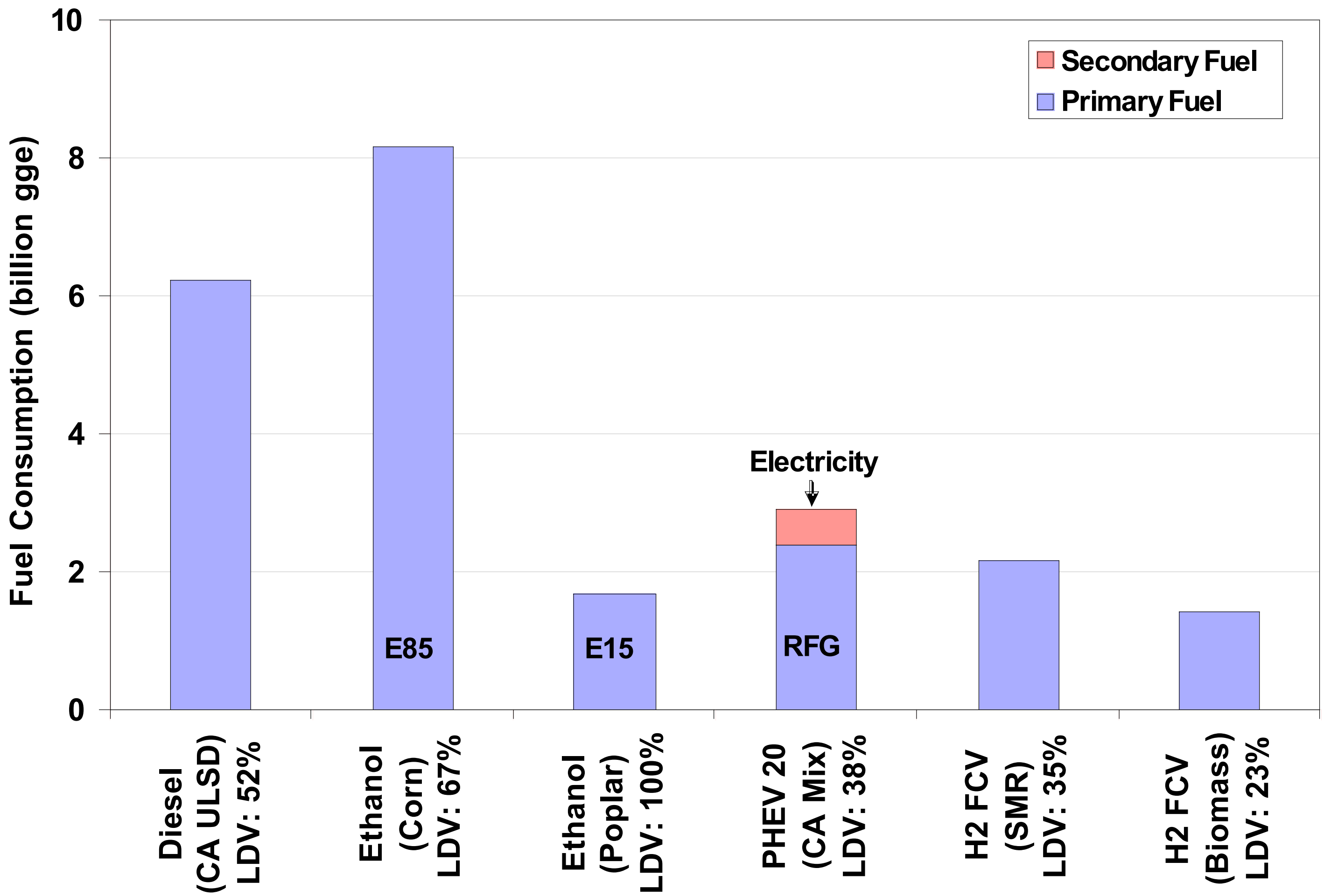
2050 Petroleum Displacement

- PHEV 1 billion
- E30 4.5 billion
- H2 7 billion

Impacts depend on new vehicle penetration

- 5 million to all vehicles

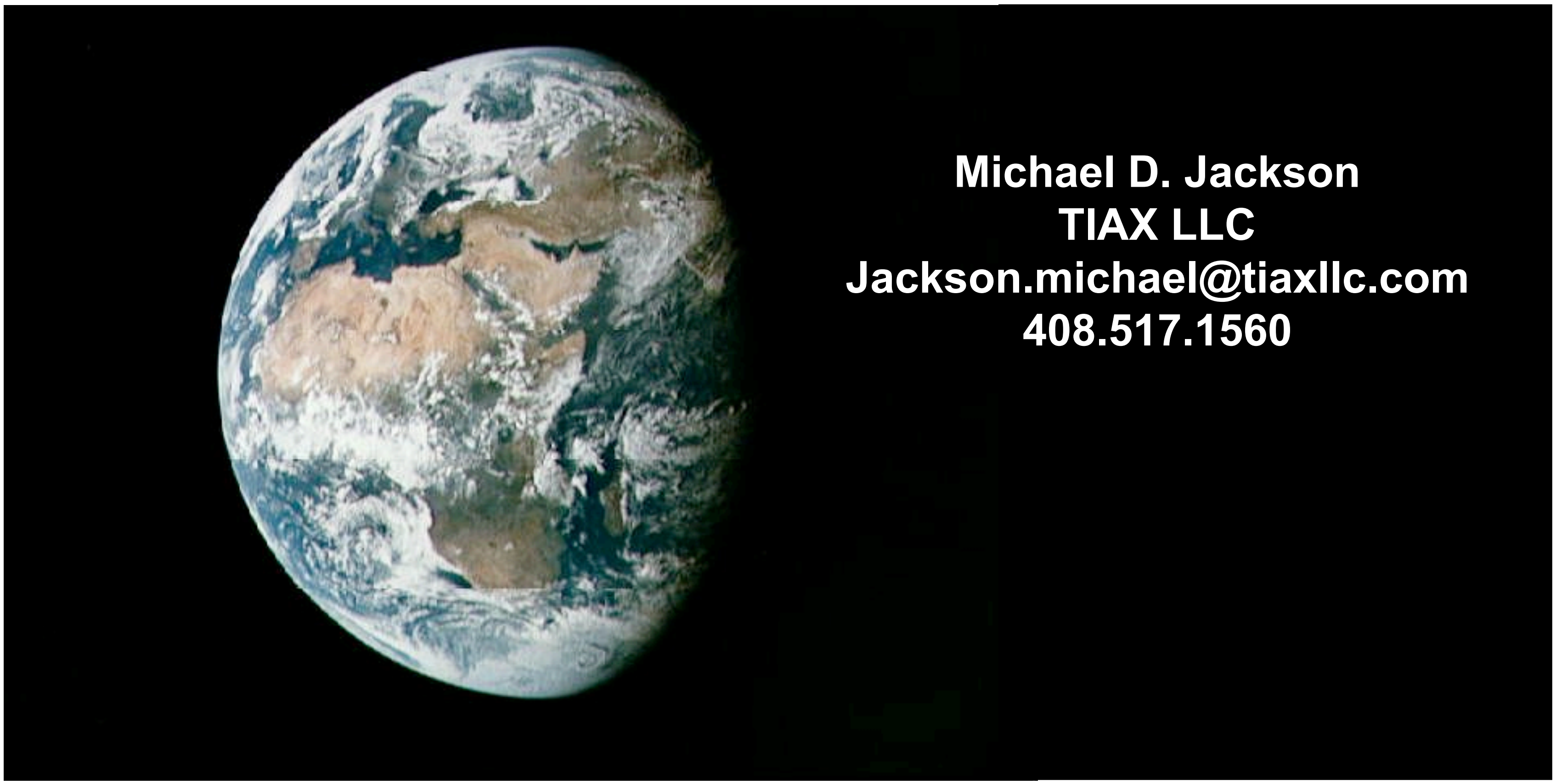
Proposed low carbon fuel standard requires at least a 10 percent reduction in carbon in gasoline and diesel fuels by 2020



FFCA is a useful tool to judge alternative strategies for reducing GHG emissions from the transportation sector

- Improved efficiency lowers GHG, criteria, and toxic emissions
  - Production
  - Distribution
  - End-use
- A variety of alternative fuel pathways will reduce both GHG emissions and petroleum consumption. Need to focus on those pathways that provide both benefits
- Electricity (depending on generation mix) provides lowest overall impact on GHG, criteria, toxic emissions and water pollution
- Biofuels very effective at recycling carbon and providing low GHG emissions, but land conversion, harvesting, collection, production, and fuel distribution affect GHG and local emissions
- Alternative fuel blends with existing gasoline and diesel fuels is also an effective strategy to reduce GHG emissions

Thank you for your Attention



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